

Chapter 2 Design Considerations

2-1. Design Approach

This manual is intended to provide, where possible, a guided approach for the design of rock foundations. The concept of guided design provides for a stepped procedure for solving engineering problems that requires solution by decision making and judgment. Any design which involves rock masses requires a decision making process in which information must be obtained, considered, and reconciled before decisions and judgments can be made and supported. As such, the manual provides a stepped procedure for planning, collecting, and characterizing the information required to make intelligent decisions and value judgments concerning subsurface conditions, properties, and behavior. A fully coordinated team of geotechnical and structural engineers and engineering geologists are required to insure that rock foundation conditions and design are properly integrated into the overall design of the structure and that the completed final design of the structure is safe, efficient, and economical. Foundation characterization and design work should be guided by appropriate principles of rock mechanics.

2-2. Types of Structures

The types of structures that require analyses as described herein include concrete gravity dams, concrete retaining walls, navigation locks, embankment dams, and similar civil works or military type structures founded on rock. Although directed toward concrete structures, parts of this manual are applicable to all rock foundations.

2-3. Design Considerations

The design of rock foundations includes two usual analyses, bearing capacity and settlement analyses and sliding stability analyses. Bearing capacity and settlement analyses involve the ability of the rock foundation to support the imposed loads without bearing capacity failure and without excessive or intolerable deformations or settlements. Sliding stability analyses involve the ability of the rock foundation or slope to resist the imposed loads without shearing or sliding. Both analyses must be coordinated and satisfied in a complete design. Basic data that should be obtained during the design stage include strike, dip, thickness, continuity, and composition of all faults and shears in the foundation; depth of overburden; ground water condition; depth of weathering throughout the

foundation; joint orientation and continuity; lithology; physical and engineering properties of the rock mass; and loading conditions. Potential failure modes and mechanisms must be determined. For foundation sliding stability, an adequate assessment of the stress conditions and sliding stability of the rock foundation must account for the basic behavior of the structure, the mechanism of transmitting loads to the foundation, the reaction of the foundation to the imposed loads and the effects of the foundation behavior on the structure. In addition to the above, the analyses of rock foundations must include an evaluation of the effects of seepage and of grouting performed to reduce seepage and the seepage effects. These evaluations are particularly important as related to assessment of hydraulic structures. Because of the difficulty in determining bedrock seepage, seepage paths, and the effectiveness of grouting, conservative assumptions should be used in these evaluations. For a discussion of grouting, see EM 1110-2-3504.

2-4. Factor of Safety

The factor of safety is defined in the manual in terms of the strength parameters of the rock mass. For analyses involving shear or sliding failures, the safety factor is defined as the factor by which the design shear strength must be reduced in order to bring the sliding mass into a state of limiting equilibrium along a given slip plane. This definition pertains to the shear resistance along a given slip surface. The derivation of limit equilibrium equations used to assess sliding stability involve converting stresses to forces. The equations satisfy force equilibrium for the limiting case. For analyses involving bearing capacity failures, the safety factor is defined as the ratio of allowable stress to the actual working stress. The safety factors described in the manual represent the minimum allowable safety factors to be used in the design of rock slopes and foundations for applicable structures. The minimum allowable safety factors described in this manual assume that a complete and comprehensive geotechnical investigation program has been performed. Safety factors greater than the described minimums may be warranted if uncertainties exist in the subsurface conditions or if reliable design parameters cannot be determined. Higher safety factors may also be warranted if unusual or extreme loading or operating conditions are imposed on the structure or substructure. Any relaxation of the minimum values involving rock foundations will be subject to the approval of CECW-EG and CECW-ED and should be justified by extensive geotechnical studies of such a nature as to reduce geotechnical uncertainties to a minimum.